Customizable Haptic and Multi-touch Gesture Interfaces On Handheld Devices for Tele-operated Robots

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Abstract— This paper presents a solution to control mobile robots by using customizable haptic and multi-touch gesture interface son handheld devices. Images coming from a camera allow both to automatically and manually control the robot. Recent advances indigital tabletop touch-and gesture-activated screens have allowed for small group collaboration. The newest generation screens simultaneously support multiple users, multiple contact points per user, and gesture recognition. To the authors' knowledge, this technology has never been applied to robot control. We envision that an interactive multi-touch screen display for robot control would improve human-robot interaction (HRI) and increase efficiency.

1. INTRODUCTION AND MOTIVATIONS

Mobile robots are gaining increasing attention in the "Internet of Things" (IoT). Indeed, on board sensors, components and appliances can be profiled and made available through semantic descriptions, which allow to move towards a highly interconnected world space. Mobile robots have a wide range of applications: manufacturing, surveillance, disaster response support, home automation, and so forth. In all these cases, a completely autonomous system would be highly desirable, but its design is particularly challenging or even not feasible yet. Therefore, robots have to be manually controlled by a human operator when required. In addition, many robots perform a specialized work that is not easily manageable using standard input controls (e.g. mouse, joystick, keyboard, and other "standard" input devices) [1]. In the last years, it has been shown that there is a need to introduce more intuitive gesture-based input devices to allow an operator to effectively control one or more robots [2].

In the field of human-robot interaction (HRI), a lot of work is based on the teleoperation of various robots, where the degree of autonomy is limited to specific tasks.

However, these robots are not intended for general users on the other hand, consumer devices do now allow researchers to design intuitive interfaces. For example, a PDA system to tele-operate a military training robot is presented [3]. PDAs and smart phones can also be used as universal interface in homes [5].

A promising solution to improve HRI seems to be represented by the use of multi-touch handheld devices whose display is exploited both for gesture input and visualization. Experiments that show the performance improvement in terms of completion times and number of actions needed to perform generic tasks using the above devices have been already investigated. For instance, in [4] the improvements that can be achieved with respect to traditional input devices (e.g. mouse) are investigated.

Nevertheless, in the real world domain that involves "things", it is likely that a user wish to interact with robots as well as with other devices in a personalized way, so that to enhance the user experience. The proposed work aims at developing a framework that allows to easily access and control remote appliance

by means of different input/output devices. Starting from a semantic description of the interface of an existing application, theframework allows to map over different devices the actions available on remote appliances, moving towards a multi-modality perspective; moreover, the framework is able to take advantage of "haptic" functionalities of devices (e.g., the vibrating alert) to improve and extend the HRI. In particular, in this paper a reconfigurable teleoperation system, which allows to remotely driving a robot using commercially available handheld multi-touch devices, is presented. The considered task consists in tracking and following moving or stationary targets through an on-board FLIR (Forward Looking InfraRed) camera that presents a twofold functionality: it allows to build an image monitoring system that can be operated under user gestures to remotely control the robot (manual mode) and it acts as a sensor aiding to take autonomous decisions (target following mode). The solution is flexible as it allows the user both to reuse interfaces based on standard input devices such as mouse and keyboard and also to work with gestures that are reconfigurable according to user preferences.

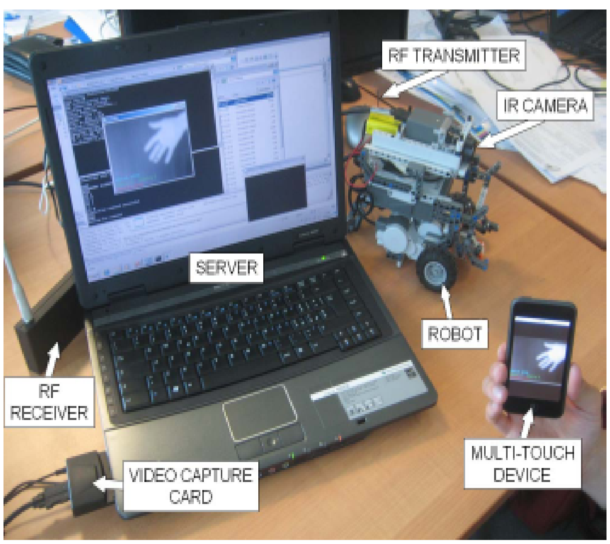

Fig 1: Elements of Teleoperation system

2. THE TELEPHONE OPERATED SYSTEM

The elements of the designed teleoperation system are shown in Figure1.An on-board IR camera is mounted on a robot and it is in charge of providing the vision functionality; the output of the IR sensor is transmitted to a server by a RF transmitter. A video capture card gathers frames from a RF receiver and dispatched FLIR images to the server, which elaborates input data and takes decisions on the controls to be sent to the robot actuators. The system has been designed to support two operation modes.

The robot can be controlled remotely by an operator through multi-touch gestures. The multi-touch device is connected to the server via a 802.11g wireless channel. Moreover, autonomous tasks can be performed by the robot through an automatic analysis of the IR images coming from the on-board camera. In particular a target tracking algorithm, based on the well-known Intensity Variation Function method [6], is used to perform target following tasks. The user can supervise the transitions between the two modes by using gestures: for instance, by touching a point in the image shown by the handheld device the robot will follow the selected target. The application running on the server is composed by multi-layer software. The bottom layer is the control software that is in charge of sending commands to robot engines. The control application could be an existing piece of software, whose interface is "parsed" in order to build a description to be later reused by the handheld device. The upper layer is constituted by a video streaming server that allows the remote user to receive the video stream and control the robot in closed-loop. An intermediate layer, named gesture server, is in charge of receiving and translating multi-touch inputs into system commands (e.g., automatic or manual mode selection,driving commands, etc.). The gesture server requires a set-up phase: control commands available at the robot side (metadata are used to describe the robot interface) are sent to the multitouch device, where the user can associate preferred gestures to selected robot actions. During the automatic target following mode, a vibrating alert is used as a warning when the target leaves the center of the image. Currently, available robot actions comprise acceleration, deceleration/reverse, and emergency stop; turn left/right, target selection. Each of these actions can be mapped to any of the following gestures: single and multiple taps, pinch in and out,one finger movements, two finger movements, pan, clockwise and counterclockwise rotations, device tilt and inclinations. Additional gestures could be easily implemented by means of various stroke recognition algorithms, thus offering the server a wider range of interaction modes. The client application running on the handheld device allows the user to configure gesture sensibility; by acting on a set of thresholds it is possible to increase or decrease robot's reactivity.Table 1 shows an example of gestures-actions translation table used during the experiment tests.

TABLE I
GESTURE MAPPING TABLE

Action	Gesture	Action	Gesture
Acceleration	one finger up	Turn left	one finger left
Deceleration	one finger down	Turn right	one finger right
Emergency stop	device tilt	Select target	single tap

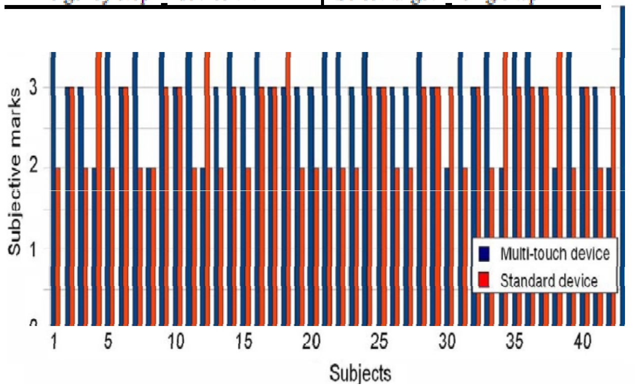

Fig: 2.Subjective evaluation results. Marks assigned by users for the multi-touch and the standard interface are in the range of 0 to 4(0: very poor; 4: very intuitive)

3. TESTS AND RESULTS

Preliminary experimental tests have been carried out both from an objective and a subjective point of view in order to assess the Effectiveness of the gesture interface. A group of users has been asked to complete a task both with a standard button-based interface and with the gesture-based interface. The task consisted in driving the robot vehicle through checkpoints along a predefined path. Objective results have been collected in terms of time needed to complete the task and total number of actions undertaken by the user. It shows that the completion time and the number of actions per task decrease by using the multi-touch interface with respect to the classic interface. Figure 2 shows the marks assigned by each user both with the gesture-based interface and the standard one, highlighting that the multi-touch interface outperforms the classic one.

4. CONCLUSION

In this paper, a reconfigurable system to perform teleoperation tasks by using commonly available consumer electronic devices is proposed. Future works will be aimed at integrating speech recognition functionalities to improve interaction experience. Moreover, additional interaction methods will be considered, e.g. by applying physics engines to simulate physics in order to provide the user the capability to control robot movements under the effect of force, mass, velocity and friction, following an approach similar to [7].

After extensive user testing with this interface, we will create design guidelines for adapting HRI to multitouch displays. This style guide reference will give the best-in-breed for this unique application of multi-touch technology.

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